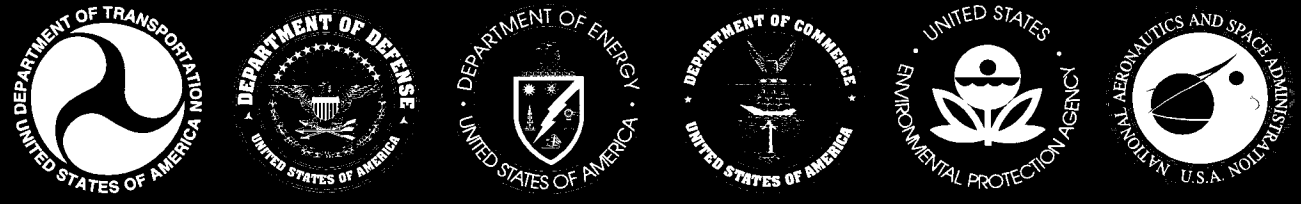
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

TRANSPORTATION SCIENCE AND TECHNOLOGY STRATEGY

Committee on Transportation Research and Development
Intermodal Transportation Science and Technology Strategy Team



September 1997

About the National Science and Technology Council

President Clinton established the National Science and Technology Council (NSTC) by Executive Order on November 23, 1993. This cabinet-level council is the principal means for the President to coordinate science, space, and technology policies across the Federal Government. NSTC acts as a "virtual" agency for science and technology to coordinate the diverse parts of the Federal research and development enterprise. The NSTC is chaired by the President. Membership consists of the Vice President, Assistant to the President for Science and Technology, Cabinet Secretaries and Agency Heads with significant science and technology responsibilities, and other White House officials.

An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research, to improving transportation systems and strengthening fundamental research. The Council prepares research and development strategies that are coordinated across Federal agencies to form an investment package that is aimed at accomplishing multiple national goals.

To obtain additional information regarding the NSTC, contact the NSTC Executive Secretariat at 202-456-6102.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization and Priorities Act of 1976. OSTP's responsibilities include advising the President in policy formulation and budget development on all questions in which science and technology are important elements; articulating the President's science and technology policies and programs; and fostering strong partnerships among Federal, State, and local governments, and the scientific communities in industry and academe.

To obtain additional information regarding the OSTP, contact the OSTP Administrative Office at

202-395-7347

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The purpose of this report is to highlight ongoing Federal research efforts in the science and technology (S&T) field and to identify new and promising areas where there might be gaps in Federal support. The report is intended for internal planning purposes within the Federal agencies and as a mechanism to convey to the S&T community the types of research and research priorities being sponsored and considered by the Federal agencies. The Administration is committed to a broad range of high-priority investments (including science and technology), to deficit reduction, and to a smaller, more efficient Federal Government. These commitments have created a very challenging budget environment—requiring difficult decisions and a well-thought-out strategy to ensure the best return for the Nation's taxpayers. As part of this strategy, this document does not represent the final determinant in an overall Administration budget decision-making process. The research programs presented in this report will have to compete for resources against many other high-priority Federal programs. If these programs compete successfully, they will be reflected in future Administration budgets.

THE WHITE HOUSE

WASHINGTON

Dear Colleague:

The Nation's transportation system stands at a historic crossroads. Changing demographics, worldwide economic growth, expanding global trade and tourism, ongoing urbanization, and safety and security concerns complicate means to satisfy increasing demands for transportation services. New and emerging technologies offer solutions to this dilemma, providing a flexible transportation system that is responsive to the changing needs of our society.

Transportation Science and Technology Strategy offers a framework to guide Federal transportation R&D to meet our national transportation goals of safety, security, energy efficiency, global competitiveness, environmental quality, and accessibility to transportation for all Americans. It responds to the greatest challenge facing the Nation's transportation system and the Federal R&D community—how to do more with less—by identifying innovative ways to partner successfully with industry and academia to leverage scarce R&D dollars.

This document builds on previous activities and reports of the National Science and Technology Council's (NSTC) Committee on Transportation R&D (CTRD). As with previous NSTC initiatives, the CTRD hopes that *Transportation Science and Technology Strategy* will promote a continuing dialogue among the elements of our national transportation enterprise, and harness the Nation's collective talents and resources to shape and advance the transportation system of the 21st century.

Sincerely,

John H. Gibbons
Assistant to the President
for
Science and Technology

PREFACE

This *Transportation Science and Technology Strategy* addresses many complex issues needed to build a transportation system for the 21st century. I am enthusiastic that the Federal Government has been visionary in moving this bold strategy for a bold nation.

President Clinton believes that "investing in technology is investing in America's future." It will be investments in transportation education, research, and technology that increase America's competitiveness in the world and our ability to create high-paying jobs for millions of Americans. A growing economy requires a transportation system that can move people, goods, and services quickly and safely.

At the beginning of President Clinton's Administration, Assistant to the President for Science and Technology, Dr. John Gibbons, asked my predecessor, Secretary of Transportation Federico Peña, to take the lead in establishing an Interagency Coordinating Committee on Transportation R&D. Under the able guidance of Deputy Transportation Secretary Mortimer Downey, we have done so. This strategy brings together the insights and lessons learned by that group.

I am committed to carrying forward these efforts and to realizing the vision set forth on these pages of a seamless and safe transportation system, with each transportation sector working effectively by itself and as part of a larger, interconnected whole to move a nation.

On these pages is the technology policy architecture that will help decision-makers build a 21st century transportation system that will keep our citizens the most mobile in the world, our economy the strongest, and our environment the cleanest. And clearly this strategy will continue into the next century my long-held belief that transportation projects are more than concrete, asphalt, and steel; they are about providing opportunities for all Americans.

Rodney E. Slater
U.S. Secretary of Transportation

NSTC COMMITTEE ON TRANSPORTATION RESEARCH AND DEVELOPMENT

Chair: Mr. Mortimer L. Downey	Deputy Secretary, U.S. Department of Transportation
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White House Co-Chair: Dr. Henry Kelly	Acting Associate Director for Technology, Office of Science and Technology Policy, Executive Office of the President
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Mr. Frank E. Kruesi	Assistant Secretary for Transportation Policy, U.S. Department of Transportation
Ms. Louise F. Stoll	Assistant Secretary for Budget and Programs, U.S. Department of Transportation
Consultant: Dr. Richard R. John	Director, Volpe National Transportation Systems Center, U.S. Department of Transportation

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EXECUTIVE SUMMARY

Careful planning is essential for managing and leveraging limited Federal research, development, and education and training resources to meet 21st century transportation challenges and opportunities.

The National Science and Technology Council (NSTC) Committee on Transportation Research and Development (CTRD) was created in 1994 to ensure that the Federal investment in transportation R&D is (1) coordinated to ensure efficient use of Federal funds aimed at this mission; (2) focused on projects identified by users, industry, and other stakeholders as being the most critical to achieving success in agencies' missions; and (3) limited to areas where it is clear that major public benefits can only be achieved through cost-shared Federal research.

Through its initial planning efforts—with major involvement of the transportation and research communities—the NSTC Committee on Transportation R&D has developed the first *Transportation Science and Technology Strategy* to help Congress, the White House, and Federal agency heads to establish national transportation R&D priorities and coordinated research activities. The Strategy is based on the results of numerous outreach events, environmental scans, and an analysis of the transportation system's current and future strengths, weaknesses, opportunities, and threats. This Strategy presents:

- A vision of the transportation enterprise.
- A likely transportation future for the year 2020.
- A set of national goals and measures encompassing safety, security, environmental quality and energy efficiency, economic productivity, and accessibility and mobility.

The Strategy has a four-tiered approach:

- Strategic Planning and Assessment
- Strategic Partnership Initiatives
- Enabling Research
- Transportation Education and Training

STRATEGIC PLANNING AND ASSESSMENT

The institutionalization of a continuing transportation R&D strategic planning and assessment process will enable policy-makers and implementers to adjust the allocation of scarce national R&D and other resources to meet changing requirements. This ongoing process, involving the establishment of a broad consensus among all levels of government, industry, and academia, will:

- Establish and assess transportation goals in accord with a changing external environment.
- Identify strategic technology partnerships to support transportation goals.
- Identify a long-term enabling research agenda to support future transportation goals.
- Develop meaningful measures of the impact of national R&D investment on meeting future transportation goals.

STRATEGIC PARTNERSHIP INITIATIVES

This Strategy, based on broad public and private sector input, identifies twelve transportation partnership initiatives that address recognized national needs, have a technology focus, and, if successful, could rely on existing market forces and the private sector for widespread implementation. In all cases, the initiatives would benefit the Nation as a whole and could not proceed in a timely fashion without some cost-shared Federal support of the overall efforts. The initiatives are intended to incorporate and guide ongoing activities that are relevant to their goals. Any new Federal components of the initiatives will be developed under the overall funding limits and constraints already established. In that context, the following proposed initiatives fall into three overlapping and interrelated categories: (1) transportation information infrastructure; (2) next-generation vehicles; and (3) transportation physical infrastructure:

Transportation Information Infrastructure

- Smart Vehicles and Operators
- National Intelligent Transportation Infrastructure
- Next-Generation Global Air Transportation
- Enhanced Transportation Weather Services
- Enhanced Goods and Freight Movement at Domestic and International Gateways

- Accessibility for Aging and Transportation-Disadvantaged Populations
- Local Environmental Assessment Systems

Next-Generation Vehicles

- Next-Generation Motor Vehicles and Ships
- Aviation Safety Research Alliance

Transportation Physical Infrastructure

- Total Terminal Security
- Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure
- Environmental Sustainability of Transportation Systems

ENABLING RESEARCH

Enabling research supports the long-term evolution of the future transportation system. As stated in the General Accounting Office report, *Surface Transportation Research Funding, Federal Role, and Emerging Issues,* as well as by numerous transportation officials, "the current mix of research projects gives too little emphasis to basic, long-term, high-risk surface transportation research." This Strategy identifies six research areas that support long-term national transportation goals whose benefits are too widely spread for any one company to recover its investment, whose cost or risk is too great for one company to bear, and whose benefits are too far in the future to meet private investment criteria:

- Human Performance and Behavior
- Advanced Materials
- Computer, Information, and Communication Systems
- Energy and Environment
- Sensing and Measurement
- Tools for Transportation Modeling, Design, and Construction

TRANSPORTATION EDUCATION AND TRAINING

The Federal Government has long supported transportation education. Yet, changes in transportation and its environment demand a more focused effort across the Government to address the evolving needs of transportation professionals and workers. This Strategy identifies four education and training initiatives that will build the professional capacity of the transportation workforce, create general public awareness of transportation benefits, ensure a globally competitive workforce, and prepare the next generation of transportation professionals with a multidisciplined education:

- Introduction of Transportation Concepts: Elementary and Secondary Education
- Vocational and Technical Training
- Transportation Degree Programs: International and Multidisciplinary
- Mid-Career Transportation Training

1. VISION

More than ever before, technological leadership is vital to our national interests. As stated in the recent National Science and Technology Council (NSTC) report, *Technology in the National Interest*, "Our ability to harness the power and promise of leading-edge advances in technology will determine, in large measure, our national prosperity, security, and global influence, and with them the standard of living and quality of life of our people."

Technology is particularly essential to the health of our transportation system. America's transportation system comprises a growing network of highways, transit systems, railroads, waterways, airports, airways, seaports, and pipelines that is critical to the Nation's vitality and economic well-being. Innovations in transportation contribute to America's global competitiveness and national security. They enhance our environment and local communities. And, perhaps most importantly, they save lives and reduce the risk of accidents and injuries.

The NSTC Committee on Transportation Research and Development (R&D) has developed this *Transportation Science and Technology Strategy* as a rationale and framework for guiding Federal partnership initiatives; long-term, strategic research; and education and training that will make our transportation system safer, more productive, and more efficient. The Strategy supports the vision of the Committee, set forth in the Strategic Planning Document published in 1995, and the Administration's national transportation goals:

> *"The Committee's vision is of a sustainable and seamless intermodal transportation system that effectively ties America together and links it to the world. This system will help citizens and businesses satisfy their needs by providing efficient, safe, secure, and environmentally-friendly transportation of people and goods. It will result from a strengthened partnership among government, academia, and the private sector focused on effective management and renewal of existing infrastructure, strategic deployment of new technologies and infrastructure, and on R&D which supports each of these."*

2. TRANSPORTATION IN THE YEAR 2020

Worldwide, a number of forces are converging to shape the direction of transportation over the next two decades. Understanding these changes is critical to formulating a vision and goals for transportation and to developing a *Transportation Science and Technology Strategy*. Key among these global changes are significant shifts in demographics, accelerated economic growth and globalization, growing urbanization and motorization, increasing concerns for safety and security, and changing technological trends.

As we enter the 21st century, these global issues and trends will present transportation decision-makers and researchers with a dilemma: how to meet the increased demand for transportation while also addressing the sometimes conflicting values of safety, security, economic productivity, environmental quality, energy efficiency, and accessibility.

In the past, changing transportation needs have typically been met through innovations in three areas: (1) transportation vehicles; (2) the physical infrastructure that supports their use; and (3) the people who design, build, operate, and maintain the vehicles and infrastructure, and who plan and manage the transportation enterprise. More and more, the burgeoning demands on the transportation system will be met through a fourth means: the development and deployment of an information infrastructure that underlies and will integrate these three areas. In fact, one component of any strategy to meet transportation needs will be the stimulation of alternatives to physical travel, where such a substitution is appropriate and effective.

Each of the four areas of innovation will be key to meeting the emerging global issues and trends discussed below and are the foundation for the planning process, partnership initiatives, enabling research, and education and training efforts that compose this Strategy.

CHANGING DEMOGRAPHICS

Two major demographic changes will influence the scope and character of world transportation demand in the 21st century: population growth and the aging of the population in the industrialized world. Over the next 25 years, world population is projected to grow from its present 5.5 billion to 8.5 billion people. By far, most of this growth will be in the cities of the developing world. The increased demand for transportation for this growing population will require the expansion of existing infrastructure—highways and transit systems—and perhaps new transportation alternatives.

While industrialized countries' populations will stabilize and perhaps even decline, there will be further aging of these populations. Today, over 12 percent of the United States' and 14 percent of Europe's population is over 65. By 2020, it is projected that over 20 percent of the

population in the industrialized world will be this age. The United States alone will experience far greater growth in its elder population—an estimated 53 million people will be over 65 in the United States by 2020. This dramatic growth in the aging population will necessitate new approaches to transportation and mobility, among them changes in traditional transit services, transportation infrastructure, and vehicles.

ECONOMIC GROWTH AND GLOBALIZATION

Although there continues to be incredible poverty throughout the world, economic growth in selected regions is providing a base for the development of newly-emerging upper and middle income classes. Gross domestic product per capita is steadily increasing in many countries. This trend is quite dramatic in newly industrialized countries, particularly in several Pacific Rim nations, such as Indonesia and Thailand. More people have more disposable income, after paying for food, shelter, and other necessities, than in any other period in human history. This income, combined with the influence of the mass media and telecommunications, will continue to create a booming travel and tourism market.

As world tourism becomes an increasing share of transportation demand, the capacity of many nations' surface and air transportation infrastructures will be strained. In parallel with growth in international tourism and travel will be corresponding increases in international goods movement. Low-cost communication and transportation networks have already resulted in a global manufacturing and marketing enterprise. In this interdependent world economy, continued growth in international trade will increase the demand for freight transportation facilities and place increasingly stringent cost and reliability requirements on transportation networks. Coupled with this, use of information networks for "virtual" conduct of business may reduce demands for some kinds of personal travel, while simultaneously increasing demands for other kinds of passenger and freight services.

URBANIZATION AND MOTORIZATION

About 45 percent of the world's population currently lives in urban areas. By 2025, it is projected that more than 60 percent of the projected 8.5 billion people in the world will be living in cities—many of them in megacities with populations of 10 million or more. Together with economic development, growth in the world's urban areas has led to a dramatic increase in the number of motor vehicles over the past 25 years. In 1970, there were 246 million vehicles registered in the world, 44 percent of them in the United States. By 1992, the world had 614 million vehicles, two and a half times the number in 1970, with only 31 percent in this country. In fact, the global fleet has been growing linearly since 1970, with each year bringing an additional 16 million vehicles. Should this trend continue, there would be more than 1.1 billion vehicles in the world fleet by 2025.

Along with the world's growing reliance on motor vehicles has come a concomitant increase in environmental and energy impacts—global carbon emissions, petroleum consumption, air pollution, and congestion. Moreover, coupled with high population growth rates and a growing vehicle fleet, sprawling urban development is a major cause of pollution, congestion, and poverty in many of the world's cities. In the United States, suburban sprawl has led to spatial disparities in the location of employment centers and concentrations of urban poor, who are now required to find work under the recently enacted welfare reform law.

SAFETY AND SECURITY OF THE GLOBAL TRANSPORTATION SYSTEM

Over the next two decades, continued growth in world transportation demand will lead to heightened concerns for transportation safety and security. For example, along with growth in automobile use will come the potential for a dramatic increase in automobile-related deaths and injuries. This is particularly true for many countries in the developing world, where the number of motor vehicles is growing far faster than the physical, legal, and institutional infrastructures needed to accommodate them. From 1968 to 1985, automobile fatalities increased by more than 300 percent in eight African countries and by almost 200 percent in six Asian nations. Even in the more industrialized countries, where safety records are typically good by historical standards, the private automobile will continue to present safety risks.

Still other concerns will arise from the growth of air transportation and its increasing use for international travel. Greater demand for air travel will place additional stress on an already overburdened aviation system. Countries will seek to accommodate demand by moving toward "free flight"—a dynamic air traffic management concept that allows pilots to choose their own routes, altitudes, and speeds in real time—and a global infrastructure for air traffic management. Questions may arise concerning the reliance of air systems on satellite and digital technologies, the increasing dependence on complex software-based aids and systems, and the need for global standards and interoperability. Moreover, the attractiveness of aviation as a terrorist target makes it likely that aviation security, as well as security in other modes of transportation, will be a major area of concern well into the 21st century.

TECHNOLOGICAL TRENDS

One clear reality of the late 20th century is the power of technology and the advances that can be achieved when it is applied in the right way, to the right problems, and in concert with more effective institutional relationships and a better understanding of the social forces that shape travel behavior, land use, and transportation needs. The magnitude and pace of improvements in the next century will depend on the investment of energy, imagination, and public and private resources made at the close of the 20th century. By 2020, advances in computer, information, and communications technologies will have dramatically changed ways of

organizing and managing transportation and business activities. With an evolved information infrastructure in place, alternatives such as telecommuting, video teleconferencing, remote shopping, banking, and research by computer will become serious alternatives to trip-making.

When trips are necessary, there will be an increasing number of potential alternatives for various transportation functions, each offering real benefits. For example, the transportation vehicles manufactured 25 years hence can be expected to offer dramatic advances in sustainability, performance, and cost, based on refinement and innovation affecting almost every component. The Administration's Partnership for a New Generation of Vehicles (PNGV) will yield significant improvements leading to lighter weight, lower-cost materials, improved emission characteristics, and greatly reduced petroleum requirements. In general, technological advances will be critical factors in ensuring that the overall transportation system is brought to its full potential in terms of life-cycle economics, energy efficiency, and minimal adverse societal impacts.

3. STRATEGIC GOALS AND MEASURES

Considering the likely transportation scenario in the year 2020, the Committee on Transportation R&D has defined a set of strategic goals and measures that encompass safety, security, environmental quality and energy efficiency, economic productivity, and accessibility and mobility. Investment in transportation research, technology, and education can significantly improve the probability of attaining these goals.

The White House and Federal agencies, in conjunction with the National Research Council (NRC), have been working to identify strategic goals and appropriate measures to determine the impact of Federal Government research and technology investments on the performance of the national transportation system. For example, over the past two years the NRC has conducted roundtables for key members of the Federal transportation enterprise and supported the definition of national transportation goals and strategic partnerships and measures.

What follows is a more detailed discussion of the five major goals upon which this Strategy is based.

STRATEGIC GOALS AND MEASURES

Provide a safer transportation system.

- *Level of reduction in transportation-related fatalities, injuries, and property loss.*

Achieve a high level of transportation system security.

- *Level of public trust and confidence in the security of the Nation's transportation network as determined from national surveys.*

Improve environmental quality and energy efficiency.

- *Number of major areas not now attaining legislatively-mandated air quality standards that reach these air quality goals by 2020.*

Foster economic growth and productivity through more effective and flexible global passenger and freight services.

- *Level of cost-effective passenger and freight throughput.*

Ensure improved access *to* and increased mobility *on* the Nation's transportation system.

- *Degree of increased and enhanced access and mobility of the elderly, the poor, and other transportation-disadvantaged populations.*

TRANSPORTATION SAFETY

A core transportation objective is to reduce deaths and injuries and to minimize the dangers associated with transportation. Worldwide, 250,000 people a year are killed in transportation accidents and over 10 million are injured. The fatality and injury rates in developing countries are three to four times those of the U.S. As the number of motor vehicles in the developing

world increases, world fatalities may reach 1 million per year, with 40 to 50 million injuries. Another consequence of growing demand will be a doubling of the world civil aviation fleet. At current accident rates, a doubling of civil aviation traffic implies more than 4,500 annual aviation-related fatalities worldwide by 2025.

Today, more than 40,000 people are killed on our Nation's highways each year—the equivalent of a DC-9 crashing and killing all of its occupants every day of the year. Many fatalities are caused by errors in driver judgment due to inadequate or untimely information necessary to avoid a collision. Human error is the most pervasive fundamental problem and the greatest limitation to improving transportation safety and efficiency. Thus, a major focus of the transportation enterprise's R&D activity is to understand the causes of, and determine the means to eliminate, human error as it relates to the safe operation of vehicles in all modes of transportation.

These and other major issues ensure that safety concerns will continue to be integral to many transportation R&D initiatives.

One potential measure of success could be the level of reduction in transportation-related fatalities, injuries, and property loss.

TRANSPORTATION SECURITY

Security is a key element in retaining the public's trust and confidence in the global transportation system. Yet, in the last few decades, the threat of hijacking and deliberate sabotage has become real and highly visible worldwide. In the aviation arena, for example, it is an enormous challenge to keep all weapons and explosive materials off an airplane carrying several hundred people and their highly varied luggage. At the same time, recent plots or actual attacks have been made against rail, subway, bus, and highway targets, both domestically and internationally.

The security of transportation's information infrastructure is another area of growing concern. A transportation system permeated with information technologies could prove highly vulnerable to malicious and terrorist attacks focused on introduction of false information into the system or interference with computer and communication system operation. As transportation systems become increasingly integrated with information systems, the potential increases for widespread system disruption and personal injury as a result of such security breaches.

One potential measure of success could be the level of public trust and confidence in the security of the Nation's transportation network as determined from national surveys.

ENVIRONMENTAL QUALITY AND ENERGY EFFICIENCY

Environmental and energy concerns affect transportation system development worldwide. Everywhere, transportation is becoming the focus of concerns about fossil fuel consumption, global warming, and air quality. For instance, current scenarios estimate that the world demand for petroleum, by far the primary fuel source for transportation, could double by 2020 to as much as 150 million barrels per day. Critical fuel supplies to a nation could be disrupted over the short or long term by local conflicts, natural disasters, economic downturns, or conscious political decisions.

As cities grow and the demand for transportation increases, the resulting growth in transportation activity places nearly unsustainable pressure on land use, traffic congestion, and air and water quality. The emissions caused by petroleum consumption contribute to both human health problems and global climate change. Cars, trucks, and other vehicles are major sources of carbon monoxide and of volatile organic compounds and nitrogen oxides—precursors of ozone and acid rain. Highways have been blamed for erosive and contaminated runoff and ruination of wetlands. At the same time, communities have formed coalitions that vigorously protest the risks of hazardous materials transport, such as oil spills, and the adverse impacts of transportation noise.

Combined with the dramatic forecasts for growth in world population and transportation demand, these issues have given environmental and energy concerns prominence on the national agenda.

> *One potential measure of success could be the number of major areas not now attaining legislatively-mandated air quality standards that reach these air quality goals by 2020.*

ECONOMIC GROWTH AND PRODUCTIVITY

Trade and tourism are areas of great significance to the world's economy. Tourism alone may be the single biggest economic activity in the world today, accounting for over one-tenth of the total global gross product. And, as population and disposable income both grow, a dramatic increase in international passenger travel can be anticipated. In particular, this trend will stimulate growth in air travel, and thus the need for user-preferred routes and schedules, new and expanded airport facilities, and associated transportation connections throughout the world.

Such growth also will stimulate the demand for finished goods, which in turn will expand growth in freight transportation services worldwide. Oceanborne trade is expected to increase at an average rate of 4.5 percent between 1994 and 2005. Just-in-time goods movement—with the goal of minimum inventories—is increasing both the number of trips made by parts suppliers and final assemblers' deliveries to purchasers, creating the need for more efficient

and reliable freight movement through urban and suburban centers. At the same time, the shift of manufacturing to the developing world and the increasing "out-sourcing" of component and parts production will necessitate increased freight movements during the manufacturing process itself.

Transportation decision-makers at all levels will need to respond rapidly to these demands for passenger and freight services. Yet, many local officials are not aware of the significance of these issues to their regions' economies or of the infrastructure and operational needs of these activities. In order to consider the entire transportation system—including all modes and the connections among them, both locally and internationally—as well as alternatives to physical travel in making major transportation decisions, transportation officials will need better planning tools, information, and technologies to assess the impacts of such choices.

> *One potential measure of success could be the level of cost-effective passenger and freight throughput.*

ACCESSIBILITY AND MOBILITY

Among the transportation enterprise's primary missions is to help local agencies provide essential, affordable transportation services to those who—because of age, disability, income, or personal preference—do not use an automobile. For example, estimates suggest that by the year 2020, 17 to 20 percent of the population will be over 65, with the fastest growing cohort those least likely to have easy access to automobile transportation—the population 85 and older. Likewise, those young or old with physical disabilities have considerable mobility needs. Welfare reform places renewed emphasis on the importance of mobility for those attempting to access and retain employment but who do not own an automobile. The spatial disparity of where new employment centers are located and where many of the poor live points to a serious mobility gap.

Together with these issues, the recent major growth in suburb-to-suburb commutes and "reverse" commuting (city center to suburb), new and decentralized employment locations, variable employment schedules, and the growing number of non-commute trips create considerable challenges for fixed-route transit services and other alternatives to private automobile travel. The challenge for the transportation enterprise will be to manage limited resources effectively to provide access and mobility for all segments of the population.

> *One potential measure of success could be the increase in travel and mobility resulting from improved access of the elderly, the poor, and other transportation-disadvantaged populations to transportation services.*

4. ELEMENTS OF THE TRANSPORTATION SCIENCE AND TECHNOLOGY STRATEGY

Careful planning is essential for managing and leveraging limited Federal research, development, and education and training resources to meet 21st century transportation challenges and opportunities.

The NSTC Committee on Transportation R&D was created in 1994 to ensure that the Federal investment in transportation R&D is (1) coordinated to ensure efficient use of Federal funds aimed at this mission; (2) focused on projects identified by users, industry, and other stakeholders as being the most critical to achieving success in agencies' missions; and (3) limited to areas where it is clear that major public benefits can only be achieved through cost-shared Federal research.

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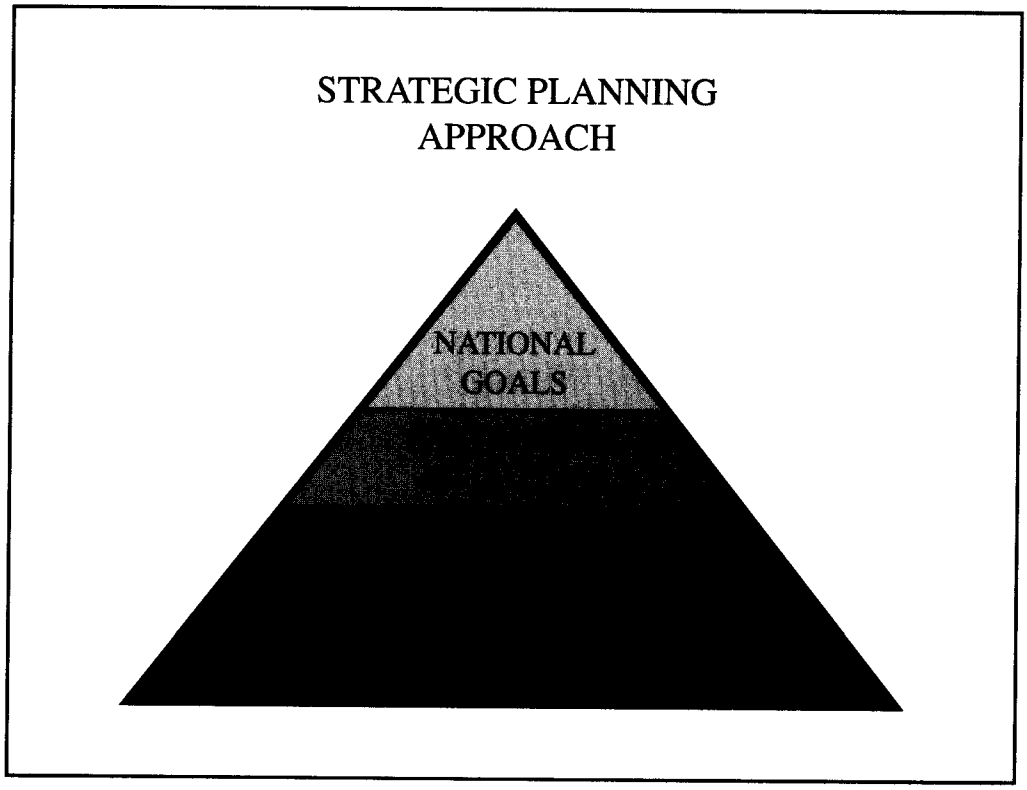
The Strategy has a four-tiered approach: (1) Strategic Planning and Assessment; (2) Strategic Partnership Initiatives; (3) Enabling Research; and (4) Transportation Education and Training.

STRATEGIC PLANNING AND ASSESSMENT

The institutionalization of a continuing transportation R&D strategic planning and assessment process will enable policy-makers and implementers to adjust the allocation of scarce national R&D and other resources to meet changing requirements. This ongoing process, involving the establishment of a broad consensus among all levels of government, industry, and academia, will (1) establish and assess transportation goals in accord with a changing external environment; (2) identify strategic technology partnerships to support transportation goals; (3) identify a long-term enabling research agenda to support future transportation goals; and (4) develop measures of progress against national goals to evaluate the impact of Federal R&D investments. Outreach to leaders in industry, State and local government, academia, the

research community, and other stakeholders has allowed the Federal Government to gather facts and analyze trends that give an objective picture of where we stand in the transportation "world," and of the external and internal pressures and factors likely to affect our future.



Federal stewardship of the overall transportation enterprise can encourage decisions and actions by all parties that contribute to seamless, efficient, and effective transportation, while balancing transportation needs against other national goals. Each year more and more stakeholders are involved in transportation decision-making, and the technical realities and uncertainties in each issue become more complex. State and local agencies must also recognize national goals—embodied in legislation such as the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Americans With Disabilities Act of 1990 (ADA), and the Clean Air Act Amendments of 1990 (CAAA)—in their transportation planning and decision-making. Information and tools for use in planning, assessing, and meeting these challenges often are difficult to obtain, are often unreliable, or simply do not exist. Support for increased planning and assessment initiatives at and among the Federal, regional, State, and local levels can be reinforced by working with individuals and agencies who are transportation stakeholders to expand their awareness of the importance of strategic planning and system assessment to their own activities, and to increase their own involvement in planning and assessment efforts.

STRATEGIC PARTNERSHIP INITIATIVES

A critical element of this Strategy is the identification of technology-based partnerships among government, industry, and academia. One of the tenets of the President's Committee of Advisors on Science and Technology is that the Nation can best profit from investments in basic science and research through partnerships and the exchange of people and ideas among Federal agencies, State and local governments, private companies, universities, public interest groups, and other stakeholders.

For agencies with transportation R&D responsibilities, strategic partnerships can expedite the research process and speed the introduction of much-needed new technologies into transportation systems and operations. Based on broad public and private sector input, this Strategy identifies twelve partnership initiatives offering some of the greatest benefits for transportation. These efforts are intended to integrate ongoing activities with new components, developed within the Federal program development process, and the overall limits established for Federal funding. These initiatives build on recommendations from various outreach events and meet all of the criteria listed in the box to the right. As shown in Exhibit A on the next page, each initiative addresses one or more of the national transportation goals. The twelve partnership initiatives are summarized below and presented in detail in Appendix B. The initiatives fall into three overlapping and interrelated categories: (1) transportation information infrastructure; (2) next-generation vehicles; and (3) transportation physical infrastructure.

CRITERIA FOR PARTNERSHIP INITIATIVES

- Addresses a real recognized national transportation system-level need.
- Has a technology focus—ideally a self-contained, readily implementable piece of technology.
- Market for the technology-based improvement exists—if successful with the technology, could rely on existing market forces and the private sector for widespread implementation.
- Is a need for a Federal role, with benefits to the Nation as a whole—taxpayers, traveling public, industry; the initiative could not proceed in a timely fashion without Federal involvement, support, or coordination, but also requires private sector cooperation and participation.

Transportation Information Infrastructure

- ***Smart Vehicles and Operators***

  Goal: Reduce the occurrence of accidents in all modes of transportation through an enhanced understanding of human performance and behavior; the application of human-centered technological aids and systems for accident avoidance; and the development of advanced materials and technologies for vehicle operator training.

EXHIBIT A

TRANSPORTATION PARTNERSHIP INITIATIVES AND NATIONAL GOALS

INITIATIVES		NATIONAL GOALS				
		SAFETY	SECURITY	ENV. QUAL./ ENERGY EFFICIENCY	ECONOMIC GROWTH & PRODUCTIVITY	ACCESS/ MOBILITY
INFORMATION INFRASTRUCTURE	Smart Vehicles and Operators	X	X		X	X
	National Intelligent Transp. Infrastructure	X	X			X
	Next-Generation Global Air Transp.	X	X	X	X	
	Enhanced Transp. Weather Services	X		X	X	X
	Enhanced Goods/ Freight Movement	X	X		X	X
	Disadvantaged Populations	X			X	X
	Local Environmental Assessment Systems			X		
NEXT-GENERATION VEHICLES	Next-Generation Motor Vehicles and Ships	X		X	X	
	Aviation Safety Research Alliance	X	X		X	
PHYSICAL INFRASTRUCTURE	Total Terminal Security	X	X			X
	Physical Infrastructure	X	X		X	X
	Environ. Sustainability of Transp. Systems	X		X	X	X

Participants: Department of Transportation (DOT: Intelligent Transportation Systems [ITS] Joint Program Office, FHWA, NHTSA, FTA, FRA, MARAD, USCG), Department of Commerce (DOC), and other Federal agencies; the technology community; vendors; States; associations of vehicle operators; railroads; transportation companies; and vehicle manufacturers.

Benefits: A safer highway, railroad, transit, and waterways system, with fewer deaths and injuries, and less suffering and property loss, accompanied by a reduction in trauma injuries for the U.S. health care system to deal with; reduced transportation vehicle repair costs; and, potentially, reduced automobile insurance premiums.

- ***National Intelligent Transportation Infrastructure***

  Goal: Deploy an intelligent transportation infrastructure across the United States within the next decade.

  Participants: DOT (ITS Joint Program Office, FHWA, FTA, FRA); State DOTs; Metropolitan Planning Organizations (MPOs); emergency response and law enforcement agencies; railroads; and private industry.

  Benefits: Reduction in travel times in metropolitan areas; faster life-saving emergency response and fewer congestion-related traffic incidents; more efficient public services; reduced petroleum consumption; improved air quality; increased infrastructure capacity without more costly new construction; and enhanced information system security.

- ***Next-Generation Global Air Transportation***

  Goal: Enhance aviation system safety, efficiency, and capacity by demonstrating next-generation concepts for air traffic management and validating the associated technologies, procedures, and operational benefits.

  Participants: DOT (FAA, USCG); NASA; Department of Defense (DoD); airlines; and manufacturers.

  Benefits: Improved safety and efficiency of the air transportation system in the face of increasing travel and capacity demands by flights in domestic airspace and over the oceans; advancement of the state of the art in aviation communications, navigation, surveillance, weather, and decision-support systems; promotion of government-industry cooperation in critical areas of aviation technology; and improved U.S. balance of trade for aviation technologies and products.

- ***Enhanced Transportation Weather Services***

  Goal: Improve transportation safety and efficiency by demonstrating the data-integration capabilities necessary to provide short-term, very small-scale weather forecasts.

  Participants: DOT (FAA, ITS Joint Program Office, USCG, FHWA, FRA); National Weather Service (NWS); private vendors; and State and local agencies.

  Benefits: In aviation, improved capabilities for flight planning and severe weather avoidance, greater system throughput, reduced fuel consumption, and lower deicing costs for airports; for ocean shippers, financial savings due to forecasts that allow planning for the most efficient routes; and in surface transportation, reduced highway accidents and related injuries, lower costs for trucking firms, and lower snow- and ice-control costs for State and local highway departments.

- ***Enhanced Goods and Freight Movement at Domestic and International Gateways***

  Goal: Enhance U.S. economic growth by expanding the overall share of global and domestic trade markets through advances in transportation technology and systems.

  Participants: DOT (ITS Joint Program Office, MARAD, FRA, FAA, FHWA, NHTSA); DOC; and other organizations representing the public, private, and defense sectors.

  Benefits: A more productive, competitive national economy and a more flexible, efficient, and seamless U.S. freight transportation system.

- ***Accessibility for Aging and Transportation-Disadvantaged Populations***

  Goal: Create seamless regional alternative transportation systems serving the needs of the elderly and transportation-disadvantaged while optimizing the existing human and capital investment in paratransit.

  Participants: DOT (FTA, FRA, FAA, FHWA, NHTSA); Department of Health and Human Services (HHS); private vendors; and State, regional, and local government agencies.

  Benefits: Reduced health care costs for the elderly; reduced welfare expenditures and improved job placement and retention for welfare recipients; and reduced public outlays for new equipment through improved management of existing infrastructure and assets.

- ***Local Environmental Assessment Systems***

  Goal: Further develop data, validated models, and a comprehensive knowledge base to support analysis of transportation-related environmental impacts and alternative strategies, including use of "virtual travel," by all levels of government and the private sector.

  Participants: DOT, Environmental Protection Agency (EPA), and other responsible Federal agencies; State and local environmental authorities; National Laboratories; the private sector; and academia.

  Benefits: Improved ability of government agencies to respond strategically to environmental objectives and to characterize the transportation implications of those objectives.

Next-Generation Vehicles

- ***Next-Generation Motor Vehicles and Ships***

  Goal: Develop internationally-competitive, domestically-produced motor vehicles and ships that achieve unprecedented gains in fuel efficiency, environmental performance, and operational performance, including user accessibility.

  Participants: DOT (FTA, FRA, MARAD, NHTSA, USCG); DOC; EPA; Defense Advanced Research Projects Agency (DARPA); Department of Energy (DOE); State and local authorities; National Laboratories; universities; component suppliers; fuel producers; engine and vehicle manufacturers; fuel cell producers; and new energy-conversion technology manufacturers.

  Benefits: Reduced economic vulnerability to petroleum supply curtailments; reduced emissions of greenhouse gases, ozone precursors, and fine particulate matter; improved transit service; improved intercity transportation service in high-density markets with airport capacity and landside access constraints; improved global competitiveness of U.S. truck, bus, and locomotive manufacturers; establishment of domestic manufacturers as leaders in production of new energy-conversion systems; revitalization of U.S. maritime carriers and shipyards; accessibility of new vehicles, passenger vessels, and ships to disabled users; and provision of surge capacity essential to national security.

- ***Aviation Safety Research Alliance***

  Goal: Provide the technology to reduce the fatal aviation accident rate by a factor of five in 10 years and a factor of 10 in 20 years.

Participants: NASA; DOT (FAA); DoD; airlines; manufacturers; and universities.

Benefits: Reduced aviation accidents and accident-related fatalities and improved capacity to meet safely the growing world demand for air transportation.

Transportation Physical Infrastructure

- ***Total Terminal Security***

  Goal: Develop a standardized approach to assessing the security threat at transportation facilities and implement a standard security package specifically tailored to that level of threat.

  Participants: DOT; the intelligence community; domestic law enforcement agencies; State and local transportation and law enforcement agencies; airport and port authorities; and public and private transportation service providers.

  Benefits: Greater security for transportation users and operators through the development of a standard approach for assessing vulnerabilities and risks at transportation facilities, and the collection of valuable information regarding cost-effective allocation of security resources and implementation of security measures.

- ***Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure***

  Goal: Stimulate and facilitate the effective use of both innovative and conventional construction designs, structures, materials, and methods in the rehabilitation, renewal, and replacement of the physical transportation infrastructure.

  Participants: DOT; DoD; DOE; DOC (National Institute of Standards and Technology [NIST]); National Science Foundation (NSF); Civil Engineering Research Foundation (CERF); transportation construction firms; manufacturers; and State and local transportation agencies.

  Benefits: Improved safety and economic productivity of the physical infrastructure through reduced likelihood of catastrophic failure, lower life-cycle investment for system renewal and expansion, and fewer service interruptions.

- ***Environmental Sustainability of Transportation Systems***

  Goal: Investigate the technological and behavioral implications of alternative transportation infrastructures and development patterns to determine those that minimize impacts on long-term environmental sustainability.

Participants: DOT; EPA; DOE; HHS; Department of Housing and Urban Development (HUD); the private sector; academia; non-governmental organizations; and State and local government agencies.

Benefits: Improved ability to understand the linkages between transportation and the environment, and how more sustainable transportation systems benefit society.

ENABLING RESEARCH

Innovations in transportation generally result from the application of a wide range of scientific and engineering disciplines not specific to transportation. Continual research in these areas is necessary to provide a solid foundation for the steady advances in transportation technology required to meet the demands of the 21st century. Yet, the long-term nature and often diffuse benefits of such research means that market forces may be insufficient to motivate private investment. Moreover, while many Federal agencies conduct research in these areas, that R&D is typically focused on agencies' specific concerns—not on broader national needs. Thus, as stated in the General Accounting Office report on *Surface Transportation Research Funding, Federal Role, and Emerging Issues*, as well as by numerous transportation officials, "the current mix of research projects gives too little emphasis to basic, long-term, high-risk surface transportation research."

CRITERIA FOR ENABLING RESEARCH

- Supports long-term national transportation goals.
- Benefits too widely spread for any one company to recover its investment at a profit.
- Cost or risk is too great for any individual company to bear alone.
- Benefits too far in the future to pass threshold of private investment criteria.

This Strategy identifies six long-term research areas that are consistent with the principles of the President's Committee of Advisors on Science and Technology, meet the criteria listed in the box to the right, and support one or more transportation system elements (as shown in Exhibit B). These enabling research areas are (1) human performance and behavior; (2) advanced materials; (3) computer, information, and communication systems; (4) energy and environment; (5) sensing and measurement; and (6) tools for transportation modeling, design, and construction.

Human Performance and Behavior

For transportation systems to achieve high goals for performance and cost, their design, realization, and use must be based on (1) extensive knowledge of user needs; (2) limitations

EXHIBIT B

TRANSPORTATION SYSTEM ELEMENTS AND ENABLING RESEARCH

TRANSPORTATION SYSTEM ELEMENTS	ENABLING RESEARCH					
	HUMAN PERFORMANCE & BEHAVIOR	ADVANCED MATERIALS	COMPUTERS, INFORMATION & COMMUNICATION	ENERGY & ENVIRONMENT	SENSING & MEASUREMENT	TOOLS FOR MODELING & DESIGN
INFORMATION INFRASTRUCTURE	X		X		X	X
NEXT-GENERATION VEHICLES	X	X	X	X	X	
PHYSICAL INFRASTRUCTURE	X	X			X	X

associated with human performance and behavioral characteristics; and (3) understanding of the many factors affecting the interaction between humans and automated systems.

Human error or inadequacy in vehicle or system operation, maintenance, or inspection is a leading factor contributing to safety and security problems. This arises in part because basic system design, operational procedures, or training programs do not fully take into account the characteristics likely among the people responsible for operating the system. Research in the behavioral sciences provides a critical foundation for building the needed transportation knowledge base to avoid such flaws.

Better understanding of human behavior is particularly needed in system control and operations, including the effects of fatigue, work-sleep cycles, working environment, boredom, and drug and alcohol use; response to emergency situations; testing of readiness to perform duties; and interactions among co-workers. In addition to affecting safety, problems associated with these topics cause operational inefficiencies that lower overall productivity. A broadly based research program will yield behavioral science results and methodologies for all modes of transportation, enabling more efficient use of scarce resources.

Advanced Materials

Technical advances in the defense and consumer sectors have produced a rich inventory of materials and associated structural concepts, tools, and techniques for their use. Enabling research in this area supports applications to transportation infrastructure, including the demonstration of effectiveness and long-term viability and, often, the reduction of costs to a competitive level. Examples include high-performance concrete, new steel alloys, innovative composite materials and adhesives, imaginative structural concepts, computer-aided design techniques, automated construction and maintenance tools, and new approaches to corrosion protection and control.

Similarly, transportation safety and energy use are greatly influenced by the materials from which aircraft, ships, and surface vehicles are manufactured. For example, the PNGV—seeking a three-fold increase in automobile fuel economy—is exploring the use of high-performance steel, aluminum, magnesium, and glass- and carbon-fiber composites for body structures. Each potential application of an innovative material poses new challenges in terms of material cost, manufacturing processes, joining and adhesives, characterization of failure mechanisms, environmental concerns, and cost compatibility with transportation uses.

Computer, Information, and Communication Systems

Worldwide, transportation is being transformed by the growing overlay of an information infrastructure on the existing physical infrastructure, yielding a system in which information technologies and ready access to many types of information are integrated into virtually all

elements and functions to enable greater efficiency, safety, and improved performance. Effective and rapid exploitation of these innovations will require a substantial and ongoing enabling research and development effort associated with system concepts, characterization of alternative configurational and technical choices, and development and harmonization of a wide range of standards.

For example, increased use of wireless communication throughout the society and economy will require a solid technical and economic knowledge base to support policy decisions regarding allocation and efficient use of electromagnetic spectrum and sophisticated mobile data communications technologies. Similarly, many important transportation applications use the highly-accurate Global Positioning System, or GPS, for position-finding and navigation. Many technical, as well as financial and institutional issues, must be resolved to assure that this system evolves and is managed in a manner that fully reflects the growing needs of civil transportation users. The basic standards for electronic data interchange and system interoperability are being addressed by appropriate trade and technical organizations, but the Federal Government has a critical role to play in facilitating that process. The growing complexity of intelligent systems and ever greater dependence on them for human safety and functioning of the society will require a high level of reliability and robustness. Similarly, a transportation system permeated with information technologies has significant new vulnerabilities to terrorist and other malicious attacks. Coordinated Federal research is needed in software modeling and verification techniques and in High-Confidence Systems—information systems that provide users with high levels of security, reliability, and restorability. High-Confidence Systems are resistant to failure and malicious penetration or damage, and respond to interference via adaptation or recovery.

Energy and Environment

Economic and environmental characteristics of transportation vehicles are determined to a large degree by the means by which stored energy is provided and converted into kinetic energy. Each candidate technology is typically of potential relevance to at least several modes of transportation, and many have the ability to improve both energy efficiency and emission characteristics. Research in this area includes electric propulsion and battery concepts, advanced internal combustion engines, hybrid designs, and incorporation of innovations such as fuel cells and flywheel energy storage. (Fuel cells, in particular, offer significant potential benefits in terms of energy conversion and mitigation of transportation's adverse environmental impacts.) A variety of alternative fuels are possible, each with strengths and weaknesses in terms of economics, practicality, and indirect impacts. Market forces tend primarily to motivate propulsion system research for near-term application, necessitating cost-shared Federal R&D—such as the PNGV—to explore the longer-term and higher-risk technologies.

Sensing and Measurement

The wide range of information technologies now being incorporated into transportation systems has steadily increased the value of real-time monitoring and inspection of transportation vehicles and infrastructure. "Smart structures"—roads, bridges, runways, tunnels, and others with a network of embedded sensors—can yield lower cost with increased safety margins by continually providing detailed condition status and information, under normal as well as abnormal circumstances. Similarly, "smart vehicles" depend to a large degree on sensing their environmental and operating circumstances. The benefits of coupling sensing and computing in this manner include safety, vehicle and infrastructure lifetime, and optimized maintenance practices.

Monitoring of weather and air quality has direct application to transportation. These examples make clear the value of low-cost, high-performance devices to make an extremely wide range of physical measurements, which can then be coupled to computer chips capable of generating warnings or adjusting operation directly. A virtually unlimited number of physical mechanisms and sensing concepts are potentially available, but devices of special importance to transportation will be identified and brought to fruition only to the degree that the transportation community makes these needs known and establishes their potential economic and operational value.

Tools for Transportation Modeling, Design, and Construction

Enabling research in this area provides tools, knowledge, information, and techniques to dramatically improve the efficiency and effectiveness of (1) assessing system requirements; (2) planning and designing system improvements; (3) evaluating alternative operational concepts and strategies; (4) estimating performance characteristics likely to result from innovations; and (5) managing system operations. Specific areas of research include:

Transportation System Design Tools: Tools and methods—such as computer models and simulations and computer-aided design, integrated across all institutions involved in the planning process—that support system planning and design, including process re-engineering, with emphasis on broad system engineering and integration to assure that the resulting system makes effective use of all components in efficiently achieving a high level of performance.

Characterizing and Modeling System Performance and Impacts: Means by which system performance—such as mobility, safety, security, and economics—is measured, assessed, and integrated into system design and operation processes and decisions.

Transportation and Logistic System Operations and Management: Information technology and other tools to support operation and management of transportation and logistic

systems, and to assure seamless integration across organizational, modal, and institutional interfaces.

Transportation Planning, Economics, and Institutions: Development of a broad knowledge base and identification and characterization of needs and interests of all parties involved with the transportation system; and understanding the economic, financial, and institutional context for transportation.

TRANSPORTATION EDUCATION AND TRAINING

The Nation's investment in research and technology is critical to the transportation system's safety, efficiency, and capacity to support national goals. Equally important, however, is our continuing investment in the human capital, the transportation professionals and workers who are responsible for the design, construction, operation, and maintenance of the system.

The Federal Government has long supported transportation education. Current programs administered by DOT are crucial to ensuring the professional capacity of the transportation enterprise. The University Transportation Centers Program, the Eisenhower Transportation Fellowship Program, the Aviation Education Program, and the National Highway, Transit, and Maritime Institutes are representative of the Federal Government's continuing investment in transportation education and professional enhancement.

Transportation today is undergoing great change—experiencing advances in technology, undergoing organizational transformation, and continuing globalization along with the world economy. These changes require that current and future generations of transportation professionals and workers be responsive to a more complex and dynamic environment:

Advanced Technology: Transportation technology once focused on traditional building materials, standard construction techniques, and combustion-engine-powered vehicles. Newly developed and deployed transportation technologies reflect advances in telecommunications, information systems, energy storage, and advanced electronics and materials. The transportation professional and worker must be educated and trained to adapt these technologies to the existing transportation infrastructure. Moreover, these new technologies require a supply of new workers, as well as retrained workers, to operate and maintain these new systems.

Organizational Transformation: The transportation organizational environment continues to change. ISTEA gave more decision-making authority to State transportation agencies and MPOs. Likewise, the movement toward intermodal planning, finance, and operations has resulted in many changes, including highway departments evolving into State "transportation" departments. These new agencies are only now learning to address the competing needs of regional public mobility and freight movement with environmental and

societal concerns. The combined impacts of devolution and transportation agency changes demand that professionals be taught the most effective and innovative management techniques.

Globalization: Transportation continues to reflect a global economy. Manufacturing and logistics chains now rely on the transportation operations and facilities of many countries. Likewise, increased world business and leisure travel requires that transportation professionals be aware of changing customer needs. For example, Japan, France, and Germany require their university transportation students to work in transportation abroad prior to graduation to provide them with a better understanding of global transportation operations.

These changes demand a new focus on initiatives to address the evolving needs of the transportation workforce. This Strategy defines four key education and training initiatives that meet the criteria listed in the accompanying box.

CRITERIA FOR EDUCATION AND TRAINING

- Build professional capacity of industry and State/local transportation agency staffs.
- Create general public awareness of transportation benefits.
- Ensure a globally competitive workforce.
- Prepare next-generation transportation professionals with multidisciplinary education.

Introduction of Transportation Concepts: Elementary and Secondary Education

Transportation permeates every aspect of the Nation's economy, yet little effort is made to show elementary and secondary students the connection between their studies and the transportation systems around them. Many students are lost to the transportation profession simply because they have been given no incentive to pursue subjects such as mathematics and science that are essential to advancing in the field. Of even greater importance is the school system's responsibility to produce citizens capable of making informed choices in a democracy. This Nation is shortchanging itself and its posterity when it fails to provide its young people with the knowledge of how transportation systems connect them to each other and the world. This initiative will stimulate collaborative public-private partnerships to assist educators in developing and delivering transportation education modules that are fully integrated into the curriculum for each grade level.

Vocational and Technical Training

Transportation has been and continues to be a major source of the Nation's jobs. The need for well-trained and efficient transportation workers is crucial to the safety and competitiveness of the transportation system. This initiative supports collaborative investments with vocational schools, community colleges, and industrial training institutes to ensure a steady supply of capable workers to the transportation enterprise.

Transportation Degree Programs: International and Multidisciplinary

This initiative will build upon existing DOT programs to foster the development of transportation degree programs based on multidisciplinary curricula. In the face of increasing globalization of transportation, the Nation's institutions of higher learning must prepare their graduates to deal with transportation as a complex issue of systems with global dimensions. This program will assist universities in their development of multidisciplinary programs focused on identifying and resolving transportation issues in an increasingly international arena.

Mid-Career Transportation Training

Dramatic changes in technology and organizational transformations have left many transportation professionals and workers unprepared. Where technologies and training once changed only every 20 years, today the half-life of rapidly advancing technologies may be anywhere between three and five years. Such rapid development requires that current workers and professionals be educated in the latest technological advances in ITS, diagnostics, materials, command/control systems, and related applications. Likewise, transportation agency managers require the management tools necessary to meet their new responsibilities and evolving missions. This initiative will ensure that the current generation of transportation workers and professionals has the capacity to apply the most innovative technologies and techniques.

5. CONCLUSIONS

As discussed, a key tenet of the President's Committee of Advisors on Science and Technology is that the Nation can best profit from investments in basic science and research through strategic partnerships among government, industry, and academia. By partnering with private companies, State and local governments, universities, public interest organizations, and other stakeholders, Federal agencies can expedite the research process and speed the introduction of much-needed new technologies. As we enter the 21st century, this will be particularly critical for transportation, where both the challenges and the opportunities are great.

The CTRD's *Transportation Science and Technology Strategy* presents a vision for transportation in the next century and identifies the technology partnerships, enabling research, and education and training needed to achieve national transportation goals. Implementation of this Strategy will allow this Nation to meet the increased demand for transportation while balancing the sometimes competing values of safety, security, environmental quality and energy efficiency, economic productivity, and accessibility and mobility. This Strategy will help U.S. industry to compete in global transportation markets and create new, high-wage jobs at home. Most important, this Strategy will ensure that the next generation of Americans enjoys an even greater level of transportation safety, efficiency, environmental protection, and mobility than we Americans enjoy today.

APPENDIX A

RECENT OUTREACH AND ENVIRONMENTAL SCANS IN TRANSPORTATION

- Transportation Research Board Roundtable on Research and Technology Performance Measures (November 1996).
- Transportation Research Board Roundtable on Transportation Technologies (October 1996).
- General Accounting Office Report: *Surface Transportation Research Funding, Federal Role, and Emerging Issues* (September 1996).
- Seminar Series on Critical Issues in Transportation for the Twenty-first Century (Volpe Center). Proceedings.
    - Emerging Issues in Transportation Information Infrastructure Security (May 1996).
    - Current and Future Federal Applications of Tagging and Tracking Technology (June 1996).
    - Mesoscale Weather Forecasting: Technological and Institutional Challenges (July 1996).
    - Spectrum Availability and Digital Communication Links (August 1996).
    - Travel and Tourism as the World's Largest Industry: Transportation Challenges and Opportunities (September 1996).
    - Transportation Health Effects: A Current Assessment (October 1996).
- Prospectus: *Initiatives to Define R&D Issues Associated with Deployment of Information Technologies in Transportation* (Prepared by Volpe Center for Director of Technology Deployment, Office of the Secretary of Transportation [OST], in support of NSTC, September 1996).
- Symposium on Challenges and Opportunities for Global Transportation in the 21st Century (Volpe Center, October 1995). Proceedings.

- Conference on Intelligent Transportation Systems and the National Information Infrastructure (Volpe Center, Harvard University, and Massachusetts Institute of Technology, July 1995).

- Forum on Future Directions in Transportation R&D (NSTC and Transportation Research Board/National Research Council, Washington, DC, March 1995).

- Transportation Research Board Special Report 244: *Highway Research: Current Programs and Future Directions* (1994).

- Improved Techniques for Air Quality Measurements (Volpe Center, April 1994). Proceedings.

- Sustainable Transportation: Developing a Framework for Policy Innovation (Volpe Center, December 1993). Proceedings.

- Promoting Transportation Applications in Defense Conversion and Other Advanced Technologies (Symposium Series for Secretary Peña). Proceedings.

    - University of Michigan (September 1993).

    - University of California, Davis (October 1993).

    - Massachusetts Institute of Technology (October 1993).

    - University of Texas, Austin (November 1993).

- Working Together: Transportation Opportunities for Technology Reinvestment (Volpe Center, May 1993). Proceedings.

- Charting a New Course in Transportation: Transportation Strategic Planning Seminars (Eight Seminars Conducted by Volpe Center for OST, December 1991). Proceedings.

    - International Competitiveness.

    - Technological Innovations and Human Factors in Transportation.

    - Intermodal Passenger and Freight Transfer.

    - Energy, Clean Air, and Other Environmental Factors.

    - Freight Transportation.

- Urban and Suburban Transportation.
- Intercity Passenger Transportation.
- Rural Transportation.

- First International Congress on New Information Technologies and Operations Research Methods in Transportation and Telecommunications (Volpe Center, August 1991). Proceedings.

- Getting to 2020: The Process of Introducing New Technology (Volpe Center, Presented at Airshow Canada Symposium, August 1989).

APPENDIX B

STRATEGIC PARTNERSHIP INITIATIVES

This appendix provides greater detail about each of the strategic partnership initiatives identified in the CTRB's *Transportation Science and Technology Strategy*. As in Section 4, these initiatives are grouped here into three categories: (1) transportation information infrastructure; (2) next-generation vehicles; and (3) transportation physical infrastructure.

TRANSPORTATION INFORMATION INFRASTRUCTURE

Smart Vehicles and Operators

The first priority in safety is prevention—stopping accidents before they occur. The great majority of transportation accidents involve at least some degree of operator error brought on by fatigue, inattention, or incapacitation. An appropriate response to these concerns can be formulated only on the foundation of a solid understanding of human characteristics as they relate to vehicle operation.

Initiative: Smart Vehicles and Operators.

Goal: Reduce the occurrence of accidents in all modes of transportation through an enhanced understanding of human performance and behavior; the application of human-centered technological aids and systems for accident avoidance; and the development of advanced materials and technologies for vehicle operator training.

Participants: DOT (ITS Joint Program Office, FHWA, NHTSA, FTA, FRA, MARAD, and USCG), DOC, and other Federal agencies; the technology community; vendors; States; associations of vehicle operators; railroads; transportation companies; and vehicle manufacturers.

Benefits: A safer highway, railroad, transit, and waterways system, with fewer deaths and injuries, and less suffering and property loss, accompanied by a reduction in trauma injuries for the U.S. health care system to deal with; reduced transportation vehicle repair costs; and, potentially, reduced automobile insurance premiums.

Technical advances, particularly in information technologies, now offer many possibilities in terms of devices to warn operators of unsafe circumstances, or to suggest or even initiate corrective actions. The ITS program, for example, specifically includes elements intended to assure full exploitation of these opportunities. Additionally, innovative means of inspecting and monitoring the condition of vehicle and infrastructure components, periodically or while in operation, can make it possible to take corrective action before an accident occurs.

This partnership initiative incorporates a wide variety of R&D activities associated with accident avoidance. For conciseness,

these activities are discussed here in three broad groups: human performance, accident avoidance technologies, and operator training and education.

Human Performance: Research directed toward a better understanding of operator performance in transportation systems now offers great promise. As new research results are incorporated in vehicles, infrastructure, and overall system design and operation, and accompanied by new technological aids to provide information and alerts to operators, dramatic safety benefits will result. Among other activities, this initiative will support the development of new simulator capabilities, such as those now being completed for motor vehicle operator research, that will add substantially to the understanding of operator behavior and decision-making, and assist in the evaluation of the human-machine interface.

Accident Avoidance Technologies: An important use of advanced information technology in transportation is the deployment of devices to improve operator awareness, warn operators of hazardous circumstances or imminent threats, or initiate responses to hazards. The ITS program, for example, includes a substantial component that seeks to exploit these possibilities through vehicle-wayside communications, whether by on-board devices or variable message signing. This proposed initiative will assess the potential of an additional category of opportunities for preventing accidents—vehicle-based systems, such as Positive Train Control. Other such systems include "smart ships," vessel tracking systems, air traffic alert and collision avoidance systems, synthetic vision (e.g., night vision aids), smart cruise control, collision warnings or automated braking, devices to detect vehicles in "blind spots," and sensors to detect that operator alertness has dropped to a hazardous level.

Training and Education: Even with a greatly improved understanding of human performance and a set of advanced collision-avoidance technologies that draw upon that knowledge, training and education will continue to be vital to ensure that vehicle operators are knowledgeable about safety systems and safe operational procedures for the vehicles they operate. This initiative will support the development of interactive programs (e.g., CD-ROM video games, simulators) to train and evaluate vehicle operators under a wider range of operational scenarios than is currently possible.

National Intelligent Transportation Infrastructure

Over the last decade, traffic in metropolitan areas has increased at a far faster rate than available road capacity. The daily vehicle-miles traveled (VMT) per lane of urban highway has grown by nearly 30 percent, and this has led directly to greater congestion, energy use, air quality problems, and sprawl. During the past 15 years, both the number of trips per person and the miles per trip have increased at about three times the rate of population growth. VMT in urban areas have been growing at about four percent a year. In the face of this explosive growth in

travel, the transportation system's capacity has not kept pace. DOT estimates that to just match the growth in VMT, the U.S. transportation system would need to build approximately 35 percent more highway capacity. Doing so for 50 of our most congested metropolitan areas—for which the total cost of congestion is $43 billion a year—would cost about $150 billion. At the same time, all levels of government currently invest only about $40 billion in the entire transportation infrastructure each year.

Initiative: National Intelligent Transportation Infrastructure.

Goal: Deploy an intelligent transportation infrastructure across the United States within the next decade.

Participants: DOT (ITS Joint Program Office, FHWA, FTA, FRA); State DOTs; MPOs; emergency response and law enforcement agencies; railroads; and private industry.

Benefits: Reduction in travel times in metropolitan areas; faster life-saving emergency response and fewer congestion-related traffic incidents; more efficient public services; reduced petroleum consumption; improved air quality; increased infrastructure capacity without more costly new construction; and enhanced information system security.

Congestion also has an impact on commercial motor vehicle travel, particularly when coupled with the administrative burden associated with regulatory compliance. Motor carriers are legally required to obtain numerous and information-intensive credentials and clearances for interstate operations. On the average, interstate carriers may deal with five or six public agencies within each of the States in which they operate. Regulatory compliance not only creates administrative inefficiencies and redundancies, but it increases labor costs. Total compliance costs for the industry are estimated to be as high as $5 billion a year. The costs to the public sector are even greater, due to the volume of paperwork associated with motor carrier inspections, issuance of credentials, and tax collection.

Rural transportation poses yet another set of challenges. The transportation needs of rural areas differ significantly from those of cities. Although less than 40 percent of annual VMT are on rural roads, these roads account for 60 percent of all traffic fatalities because of higher speeds and relatively slow emergency response. Many rural residents are isolated, without a car or access to public transportation. Thirty-eight percent of rural residents live in areas without any transit services; another 28 percent live where the level of service is negligible. Moreover, visitors to rural tourist areas have limited access to directions and to other basic travel information.

Intelligent transportation systems, or ITS, offer promising solutions that respond to these pressing challenges in urban, commercial, and rural surface transportation. These systems are diverse and versatile, combining telecommunications, computer, sensing, and electronics technologies to provide real-time information to traffic managers and travelers on traffic, weather, navigation, and vehicle diagnostics—in much the same way that the air traffic control system does for air traffic—to achieve greater system efficiency, safety, and convenience.

In partnership with State and local agencies and industry, this partnership initiative will support the creation of a national intelligent transportation infrastructure—a transportation communications and information backbone—that will help to ensure that the various ITS strategies being deployed across the country are integrated, interoperable, intermodal, and secure. This national infrastructure comprises three broad systems:

Metropolitan ITS Infrastructure: This infrastructure will integrate advanced traffic management, traveler information, and public transportation systems to meet the needs of metropolitan areas.

Commercial Vehicle Information Systems and Networks: This effort will integrate data, technology, and communications systems to make safety regulation of commercial vehicles faster and more effective, and to make compliance transactions more efficient for both motor carriers and regulators.

Rural ITS Infrastructure: This infrastructure will upgrade communications and information technologies in rural communities and link rural areas to the metropolitan information infrastructure.

Through this initiative, Federal agencies will work with industry, and State and local partners to deploy various elements of this overall infrastructure. The Federal role will include providing incentives for deployment, supporting public-private model deployments and technology demonstrations, developing innovative financing and acquisition processes, promoting the acceptance of national standards, providing training and technical assistance, and pursuing focused research and development. A major component of this effort will address the security concerns arising from opening new avenues of communication among transportation agencies, emergency services, other agencies, and the traveling public. Together with the increasing dependence on information and communication technologies, this trend has heightened transportation systems' vulnerability to information security problems.

Next-Generation Global Air Transportation

Recent government-industry partnerships have developed a number of advanced technologies for air traffic management, as well as consensus on operational improvements required for enhancing the safety, flexibility, and efficiency of air traffic management operations. In particular, the "free flight" concept, developed in collaboration with U.S. airspace users, envisions a system wherein aircraft operators have wide latitude for selecting flight paths, speeds, and altitudes that best satisfy their operational requirements; the air traffic management system imposes restrictions only to ensure that aircraft are separated and that other essential safety requirements are met.

Most of the technologies that would foster free flight have been developed and tested on a small scale. The next step in the practical application of these technologies is integration, demonstration, and validation in the operational environment. This activity not only will set the stage for national deployment of the next-generation air traffic management system, but will affirm U.S. leadership in aviation by showcasing the new technologies and promoting global markets for U.S. aviation products.

This initiative will implement and validate advanced air traffic management technologies and procedures under real-world conditions. The activity is essential to FAA and industry efforts to evaluate the consequences of changes in the operational concepts and procedures required to exploit the new technologies. The potential of the new technologies has been successfully demonstrated—on a limited scale for helicopters—at the summer Olympics in Atlanta. There, the FAA, in partnership with the Olympic Committee, industry, helicopter operators, and NASA, demonstrated the use of satellite-based navigation and surveillance techniques in managing the large number of passenger, cargo, and security helicopters supporting the games.

Initiative: Next-Generation Global Air Transportation.

Goal: Enhance aviation system safety, efficiency, and capacity by demonstrating next-generation concepts for air traffic management and validating the associated technologies, procedures, and operational benefits.

Participants: DOT (FAA, USCG); NASA; DoD; airlines; and manufacturers.

Benefits: Improved safety and efficiency of the air transportation system in the face of increasing travel and capacity demands by flights in domestic airspace and over the oceans; advancement of the state of the art in aviation communications, navigation, surveillance, weather, and decision-support systems; promotion of government-industry cooperation in critical areas of aviation technology; and improved U.S. balance of trade for aviation technologies and products.

The proposed effort would implement and demonstrate the new system in two regions, one each in Alaska and Hawaii. Hawaiian airspace is an ideal location because it is geographically isolated and serviced by a relatively small number of aircraft, making technology upgrades more affordable and manageable. Further, because Hawaii is a popular international destination, it offers a unique opportunity to showcase U.S. technologies for the rapidly growing aviation markets in Asia and elsewhere. Alaska also has the advantage of relative geographic isolation. In addition, it provides challenging weather conditions and terrain that the new system addresses by providing relevant safety information in the cockpit. The demonstration in Alaska therefore will validate the ability of the new technologies to significantly increase the safety of flight operations.

This initiative will exploit and expand existing partnerships among industry, airspace users, the FAA, NASA, and DoD. These collaborations created the concept of free flight, and have been productive in developing and testing the new air traffic management technologies that provide a

basis for the next-generation system. This partnership initiative is the essential next step in air traffic management system development.

Enhanced Transportation Weather Services

Initiative: Enhanced Transportation Weather Services.

Goal: Improve transportation safety and efficiency by demonstrating the data-integration capabilities necessary to provide short-term, very small-scale weather forecasts.

Participants: DOT (FAA, ITS Joint Program Office, USCG, FHWA, FRA); NWS; private vendors; and State and local agencies.

Benefits: In aviation, improved capabilities for flight planning and severe weather avoidance, greater system throughput, reduced fuel consumption, and lower deicing costs for airports; for ocean shippers, financial savings due to forecasts that allow planning for the most efficient routes; and in surface transportation, reduced highway accidents and related injuries, lower costs for trucking firms, and lower snow- and ice-control costs for State and local highway departments.

For the transportation system, the safety, mobility, and economic impacts of adverse weather conditions are considerable. According to a report of the Office of Science and Technology Policy (OSTP), each year weather causes or contributes to 6,000 fatalities on U.S. highways and 800 aviation-accident-related deaths. The OSTP estimates that more than half of all flight delays are attributable to weather, and that uncertainties in predicting flight-level winds add a quarter billion dollars annually to the Nation's aviation fuel bill. Moreover, the FHWA states that between 25 and 35 percent of all intercity road accidents occur during adverse weather, with the risk of accidents increasing during bad weather by a factor of from two to five.

Advances in weather technologies and meteorology during the past decade offer the promise of mitigating many of the impacts of severe weather on transportation. Among these are new observation systems, such as Doppler radars and Automated Surface Observing Systems; advances in computing speed and capacity; and greater fundamental knowledge of weather systems. In fact, weather observation and information-processing capabilities have expanded so greatly that it is now feasible to combine weather data from many sources into massive databases and manipulate the data with numerical models to produce reliable short-term weather forecasts for individual roads, traffic arteries, bridges, airport runways, air corridors, ports, and waterways. However, the full potential of such small-scale forecasting will not be realized without further improvements in weather data integration and dissemination.

The benefits of such improvements are already being demonstrated. For example, at Chicago's O'Hare International Airport, the National Center for Atmospheric Research, as part of an FAA initiative, has combined radar and sensor data to provide snowfall predictions for up to 30 minutes for one-square-kilometer areas of the airport complex. The data integration is accomplished using a high-performance computer workstation. Snowfall forecasts are displayed

in graphical form on monitors in the airport and airlines' operations centers. This same capability will be demonstrated at New York's LaGuardia Airport in collaboration with the Port Authority of New York and New Jersey.

Building upon this work and the forecasting capabilities already developed by the NWS, this partnership initiative will provide the planning and underlying infrastructure required to integrate all radar, sensor, and satellite data with local geographical information within a selected State and provide 30-minute, and eventually up to 120-minute, localized statewide weather forecasts. These capabilities will also be of significant use in furthering the goals of the Aviation Safety Research Alliance described below.

Enhanced Goods and Freight Movement at Domestic and International Gateways

Initiative: Enhanced Goods and Freight Movement at Domestic and International Gateways.

Goal: Enhance U.S. economic growth by expanding the overall share of global and domestic trade markets through advances in transportation technology and systems.

Participants: DOT (ITS Joint Program Office, MARAD, FRA, FAA, FHWA, NHTSA); DOC; and other organizations representing the public, private, and defense sectors.

Benefits: A more productive, competitive national economy and a more flexible, efficient, and seamless U.S. freight transportation system.

The Nation's economic success relies on access to worldwide markets for its goods and services. However, as other countries vie for global and U.S. markets, America's competitive position continues to be challenged. Critical to the Nation's future competitiveness is the development of an enhanced integrated transportation system for the movement of international and domestic freight, based on advanced infrastructure technologies and more efficient communication and information systems.

Today, international and domestic freight moves along integrated "pipeline" systems from origin to destination, linking various modes as required. Reliance on just-in-time production and inventory and distribution management practices has increased the demand for better freight transportation, yet inefficiencies at any point in the pipeline can disrupt the total system—resulting in reduced profits for transportation providers and higher costs for freight shippers and consumers. The goal of freight transportation R&D must therefore be to develop seamless intermodal networks for the entire trip—from origin to destination.

This partnership initiative will develop segments of such a seamless, intermodal freight transportation system. On the water side, this initiative will focus on advanced terminal design and operating systems that complement changing ship designs and operations. On the land side, this effort will incorporate advances in high-speed freight rail networks, truck/container transport and handling systems, capsule pipeline systems, truck/airport interface systems, and rail/truck/water interface systems. Each of these segments also will require the application of communication and information systems technology and infrastructure.

Accessibility for Aging and Transportation-Disadvantaged Populations

Although the United States possesses one of the safest and most extensive passenger transportation systems in the world, the system is unable to provide optimal mobility for selected and growing portions of the population. These segments include the elderly, the physically challenged, and the poor:

- Today, 12 percent of the population is 65 or older. Estimates suggest that by the year 2020, 17 to 20 percent of the population will be over 65, and the fastest growing cohort will be those least likely to have easy access to automobile transportation—those 85 and older.

- Those young or old with physical disabilities have considerable mobility needs. Transportation to medical facilities, schools, training centers, and workplaces are critical to their health and well-being.

- The transportation needs of the poor, particularly inner-city and rural populations, have been an important priority in national transportation and human service policies. However, recent welfare reform legislation requiring States to implement welfare-to-work programs places renewed emphasis on the importance of mobility for those attempting to access and retain employment.

Initiative: Accessibility for Aging and Transportation-Disadvantaged Populations.

Goal: Create seamless regional alternative transportation systems serving the needs of the elderly and transportation-disadvantaged while optimizing the existing human and capital investment in paratransit.

Participants: DOT (FTA, FRA, FAA, FHWA, NHTSA); HHS; private vendors; and State, regional, and local government agencies.

Benefits: Reduced health care costs for the elderly; reduced welfare expenditures and improved job placement and retention for welfare recipients; and reduced public outlays for new equipment through improved management of existing infrastructure and assets.

Government investment in paratransit has provided the vast majority of the transportation options available to these populations. *Paratransit* is typically defined as flexible-route, low- or medium-capacity vehicles serving a predetermined group of people, such as the elderly, for a fee. The need for these services is growing. Demand-responsive paratransit nationwide has doubled the number of miles traveled over the last 10 years to nearly 600 million miles per year.

Although paratransit fills an important transportation gap for many parts of the population, its financial viability has been underwritten with substantial government funding—Federal, State, local, and private—rather than from its own revenues. High operating costs and poor management strategies that do not optimize the use of drivers and vehicles have made such services costly and less than fully responsive to their riders' mobility needs.

This partnership initiative will improve the regional mobility of the elderly and transportation-disadvantaged through better management of paratransit operations and assets. This will be achieved by developing, deploying, and testing a program that will utilize selected information system technologies and applications, including automatic vehicle location, state-of-the-art vehicle communications, geographical information systems, computer-aided dispatch, and electronic fare collection. These technologies will be integrated into a centralized regional control system to manage otherwise independent paratransit operators. Centralized dispatch, monitoring, and fare collection for regional paratransit services provided by transit properties, Councils on Aging, and human service providers within a single region will be conducted from a regional mobility management center.

Although a number of "smart" technologies are currently being used or individually demonstrated throughout the country, no single regional testbed exists that attempts to manage all paratransit services within a region. The power and reduced cost of commercial off-the-shelf information, communication, and navigation systems makes the deployment of a regional access and mobility program possible.

Local Environmental Assessment Systems

Assessment of environmental impacts, and of the cost-effectiveness of countermeasures, is in most cases a very difficult process. For example, urban air pollution depends in part on vehicle emission characteristics, patterns of travel, weather and climate conditions, and very complex atmospheric chemistry and physics. Moreover, it is often not possible to predict accurately the travel behavior changes that may be associated with a particular air-quality change, whether involving road construction, traffic control, or demand management.

As a result, many uncertainties surround the environmental aspects of major transportation investment and regulatory decisions. This can be an especially serious problem for local government planning bodies, which often lack the sophisticated tools and technical staff needed to deal with such complex issues. Problems also can arise in the degree to which environmental regulatory agencies appreciate the transportation impacts of their decisions. Since the consequences for transportation system performance, public health, and overall quality of life can be severe, it is critical that the Federal Government conduct a wide range of research

Initiative: Local Environmental Assessment Systems.

Goal: Further develop data, validated models, and a comprehensive knowledge base to support analysis of transportation-related environmental impacts and alternative strategies, including use of "virtual travel," by all levels of government and the private sector.

Participants: DOT, EPA, and other responsible Federal agencies; State and local environmental authorities; National Laboratories; the private sector; and academia.

Benefits: Improved ability of government agencies to respond strategically to environmental objectives and to characterize the transportation implications of those objectives.

activities focused on clarifying all aspects of major transportation-related environmental issues. The recently proposed changes of U.S. standards for ambient concentrations of ozone and fine particulate matter, for example, are likely to expand the geographic scope of non-attainment. This topic also has a large international component. International agreements to limit emissions of carbon dioxide and other gases could have profound consequences for domestic transportation.

This partnership initiative will develop data and analytical models to provide a comprehensive environmental knowledge base to support decisions, policy formulation, and transportation investments in all modes. It will expand and build upon the work conducted under the Travel Model Improvement Program (TMIP), an interagency effort aimed at developing a new generation of travel demand models. The TMIP includes both research to enhance current modeling practice and a longer-term initiative to develop a new approach using the latest advances in computing technology (known as the TRansportation ANalysis SIMulation System, or TRANSIMS). This new approach uses microsimulation to depict travel patterns and couple them with a modal emissions model, allowing MPOs and other agencies to fully analyze the implications of various transportation investments on both travel characteristics and emissions.

Another need that this initiative will address is for an increased understanding of the relationship between transportation systems and land use decisions. This effort will support the development of analytical tools that MPOs and other transportation decision-makers can use to assess the implications of transportation projects for overall sustainability, including land use, economic development, and accessibility.

Such evolved planning tools will enable decision-makers to assess the impacts of different kinds of transportation improvements, coupled with appropriate zoning and supportive use of telecommunications and data links, to configure transportation systems that simultaneously meet metropolitan mobility needs and promote urban environmental quality and sustainable long-term growth.

NEXT-GENERATION VEHICLES

Next-Generation Motor Vehicles and Ships

There are four prominent national concerns which, together, will require significant advances in transportation vehicle technology. First, the U.S. relies on petroleum to provide more than 95 percent of the energy required for transportation, and it has been estimated by some researchers that even a brief supply curtailment (i.e., two years) could drain $500 billion from the economy. Second, although the U.S. has advocated the adoption of binding international commitments to stabilize the atmospheric concentration of greenhouse gases, continued growth of U.S. transportation sector emissions is projected under current policies. Third, while recent

improvements have been realized in urban air quality, additional measures for mobile sources would be required to meet tighter proposed standards for ozone and fine particles. Finally, U.S.-based component and vehicle manufacturers face growing international competition, and must continue to make technological gains to compete effectively in the world marketplace.

Initiative: Next-Generation Motor Vehicles and Ships.

Goal: Develop internationally-competitive, domestically-produced motor vehicles and ships that achieve unprecedented gains in fuel efficiency, environmental performance, and operational performance, including user accessibility.

Participants: DOT (FTA, FRA, MARAD, NHTSA, USCG); DOC; EPA; DARPA; DOE; State and local authorities; National Laboratories; universities; component suppliers; fuel producers; engine and vehicle manufacturers; fuel cell producers; and new energy-conversion technology manufacturers.

Benefits: Reduced economic vulnerability to petroleum supply curtailments; reduced emissions of greenhouse gases, ozone precursors, and fine particulate matter; improved transit service; improved intercity transportation service in high-density markets with airport capacity and landside access constraints; improved global competitiveness of U.S. truck, bus, and locomotive manufacturers; establishment of domestic manufacturers as leaders in production of new energy-conversion systems; revitalization of U.S. maritime carriers and shipyards; accessibility of new vehicles, passenger vessels, and ships to disabled users; and provision of surge capacity essential to national security.

This partnership initiative responds to these concerns through R&D leading to the development of transportation vehicles that are better designed, more efficient, and far less polluting. User accessibility issues will be considered as an integral element of the vehicle design process. Specifically, this effort will seek to develop the next generation of:

Highway Vehicles: This initiative will continue the PNGV and Advanced Technology Transit Bus (ATTB) activities and will supplement them by also focusing on dramatic improvements in medium- and heavy-duty-vehicle fuel efficiency. In 1993, the Clinton Administration joined in a historic partnership, the PNGV, with the Big Three automakers to establish global technical leadership in the development and production of affordable, fuel-efficient, low-emission automobiles that meet today's safety and performance standards. However, while automobiles account for 40 percent of the Nation's transportation energy demand, heavy vehicles—buses and trucks—still consume 25 percent of the total energy used for transportation. These vehicles, which tend to use diesel fuel, are also responsible for major shares of transportation sector emissions of nitrogen oxides and fine particles. In recent years, the FTA has worked collaboratively with the transit industry, DARPA, and DOE to develop the first prototype ATTB. This bus uses lightweight composite materials and an electric drivetrain to achieve a four to five ton reduction in curb weight, low emissions, and reduced fuel consumption.

Locomotives: Applications in the U.S. for high-speed trains require a non-electric high-acceleration locomotive. Although most high-speed technology uses electric propulsion, virtually the only portion of the U.S. rail system currently electrified is the Northeast

Corridor—and the cost of electrification is daunting. This partnership initiative will support the development, test, and demonstration of non-electric, high-speed rail technology to establish a technological context in which State and local governments and private industry can proceed to implement new rail services.

Ships: International freight transport is critical to this country's participation in the global economy. Total oceanborne foreign trade in 1994 had a value of $566 billion, up 13 percent from the previous year. Moreover, commercial sealift is the primary means of sustaining military forces deployed abroad. Sufficient capacity, including readiness for conversion of ports and a portion of the commercial fleet from civil to defense functions, is essential to national security. It is thus important to the Nation that there be a U.S. merchant fleet capable of competing internationally on a cost and service basis.

By supporting focused R&D designed to stimulate and foster innovation in ship design and shipbuilding, this initiative will provide Federal participation and leadership necessary to ensure national defense readiness and to restore the health of the U.S. maritime industry. The President's shipbuilding revitalization program already includes an R&D element called MARITECH, which focuses on advanced commercial ship designs and modernization of shipyard facilities, processes, and procedures.

R&D activities need to address not only ship structure but also ship propulsion issues. For example, recent Navy demonstrations of fuel cells could form the basis for a partnership with the USCG to develop this technology for wider use in ships and, potentially, for land transportation vehicles such as locomotives, buses, trucks, and automobiles.

Aviation Safety Research Alliance

Great strides have been made over the past 40 years to make flying the safest of all of the major modes of transportation. Aviation accidents have leveled off to extremely low rates. However, although the accident rate is very low, it has stayed relatively constant for the past decade or so. Moreover, the significant projected growth in air traffic in response to global demand has the potential to cause the total number of accidents to rise dramatically throughout the entire aviation system over the next 20 years.

Initiative: Aviation Safety Research Alliance.

Goal: Provide the technology to reduce the fatal aviation accident rate by a factor of five in 10 years and a factor of 10 in 20 years.

Participants: NASA; DOT (FAA); DoD; airlines; manufacturers; and universities.

Benefits: Reduced aviation accidents and accident-related fatalities and improved capacity to meet safely the growing world demand for air transportation.

This partnership initiative addresses these long-range issues proactively through an alliance

between government and industry to develop and deploy innovative technologies and products that (1) reduce human-error-caused accidents in aviation by a factor of 10 over 20 years; (2) eliminate hazardous weather as a cause of aviation accidents; and (3) reduce by half accidents due to malfunctions of safety-critical aviation systems. It builds on established cooperative programs and working relationships among DOT/FAA, DoD, NASA, and the air transportation industry. However, the FAA will continue its research that focuses on addressing immediate operational safety issues and results most frequently in safety-critical rule-making. In contrast, the innovations that will be the outcomes of this research alliance will be developed for incorporation by industry as new products in future aircraft or as additions or alterations to existing aircraft or procedures. Specific areas for this long-range technology development include:

Aircraft Systems: Prevent malfunctions of aircraft equipment and systems through innovations in aircraft design, manufacture, monitoring, inspection, and repair prior to malfunction.

Human Factors: Eliminate human-caused mishaps through human-centered aircraft and system design, alternative procedures and processes, and improved education and training.

Environment: Ensure separation between aircraft and hazardous weather, terrain and obstructions, other aircraft and their wakes, and hostile action (military/security).

TRANSPORTATION PHYSICAL INFRASTRUCTURE

Total Terminal Security

The years since the outbreak of terrorist incidents in the 1960s have seen an intermittent cycle of both increases and declines in major incidents of public terrorism or violence throughout the world. The occurrences of such incidents is often, of course, heavily dependent on local or regional political circumstances. However, recent events in both the U.S. and other parts of the world—including the bombings of the World Trade Center, the Federal Building in Oklahoma City, and Olympic Park, and several attacks against transit operations in such widely scattered cities as Tokyo, Paris, and Baku—have focused considerable attention on the vulnerability of transportation facilities and the potential for another upsweep in the number and severity of terrorist attacks.

Because of their visibility, transportation facilities have frequently been the target of such incidents. It is only prudent that transportation officials carefully study the potential threat to their own facilities and operations and develop cost-effective measures that can be taken to minimize the number and severity of incidents. Doing so, however, will require the participation and assent

of all agencies and organizations active in this area, including Federal, State, and local agencies with transportation, law enforcement, and threat-analysis responsibilities; airport and port authorities; and private transportation service providers.

Initiative: Total Terminal Security.

Goal: Develop a standardized approach to assessing the security threat at transportation facilities and implement a standard security package specifically tailored to that level of threat.

Participants: DOT; the intelligence community; domestic law enforcement agencies; State and local transportation and law enforcement agencies; airport and port authorities; and public and private transportation service providers.

Benefits: Greater security for transportation users and operators through the development of a standard approach for assessing vulnerabilities and risks at transportation facilities, and the collection of valuable information regarding cost-effective allocation of security resources and implementation of security measures.

This initiative will modify an approach taken by the State Department for application to major transportation terminals, facilities, and operations. This concept, called "Total Terminal Security," will enable the transportation community to apply a standard, acceptable methodology to the allocation of security resources and implementation of security measures at each location. In practice, this concept will cover the range of major security elements, including physical security and public access controls, personnel security, perimeter security, technical security, and, where relevant, communications and information systems security.

One example of a transportation facility to be included in this approach is domestic airports. Under this initiative, new systems for detecting weapons and explosives will be incorporated with other developments in physical security, and with passenger profiling, into a "package" implemented at three to five airports to assess its effectiveness as a total integrated system. The selected airports will become operational laboratories for validating the integration of airport and airline security, new security technology, and the participation of various organizations such as local government agencies, the Federal Bureau of Investigation, and others. Using three to five different airports will help to identify problems that may arise when the total security concept is applied to specific sites. The airports' security systems will be evaluated in terms of passenger and cargo throughput, delay time due to the inspection process, and operating costs. If the total security concept works as well as expected, the test airports will serve as models for the rest of the Nation's airports and for the international community.

This airport security activity is already well under way. The FAA has accomplished simulations of total security packages and, based on these simulations, has developed projected deployment plans. This initiative would expand current work to the three to five operational tests at airports and develop similar integrated security packages for other transportation facilities.

Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure

Initiative: Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure.

Goal: Stimulate and facilitate the effective use of both innovative and conventional construction designs, structures, materials, and methods in the rehabilitation, renewal, and replacement of the physical transportation infrastructure.

Participants: DOT; DoD; DOE; DOC (NIST); NSF; CERF; transportation construction firms; manufacturers; and State and local transportation agencies.

Benefits: Improved safety and economic productivity of the physical infrastructure through reduced likelihood of catastrophic failure, lower life-cycle investment for system renewal and expansion, and fewer service interruptions.

The Nation's transportation infrastructure is aging—its elements either nearing or exceeding their design life. This aging infrastructure must be incrementally restored, renewed, and strengthened. Many elements also require capacity expansion if our growing needs for transportation are to be met. Yet, there is a pressing need to "do more with less" in maintaining the physical infrastructure for surface, air, marine, and multimodal nodes in transportation. The DOT Report to Congress, *1995 Status of the Nation's Surface Transportation System: Conditions and Performance,* estimated that an annual investment of approximately $57 billion would be required from all sources just to maintain current conditions (including congestion remediation), with $80 billion required to provide a higher level of service by correcting existing deficiencies. Moreover, several major airports, which were not addressed in this report, suffer from severe and growing congestion and delays, and capacity shortfalls in the ground systems serving them, while more than $4 billion is spent each year to maintain, repave, and expand existing runways.

Reducing the backlog of needed infrastructure rehabilitation and renewal, and meeting the critical need for improved infrastructure performance and capacity, poses major challenges in terms of life-cycle cost, safety, reliability, and environmental impacts. The growing maintenance funding gap can be bridged only by restructuring the technology base for physical infrastructure renewal.

This initiative proposes joint strategic R&D investments in key technologies to ensure the safe operability of the aging infrastructure and the timely detection of deteriorating conditions. These infrastructure technologies fall within three areas:

Renewal Engineering: This technology area covers the use of improved materials, designs, and methods for infrastructure renewal. Specific technologies include new construction methods such as automation and robotics, trenchless and other advanced tunneling, and efficient cut-and-cover; advanced structural materials, including durable composites and metal-composite hybrids; and advanced paints and spray coatings.

Advanced Infrastructure Inspection, Monitoring, and Maintenance: Included in this technology area are nondestructive test and evaluation technologies and "smart" sensors

and materials, such as embedded fiber optics for visual inspection or strain interferometry, shape-memory alloys, and ultrasonic or magnetic corrosion detection.

Environmental Engineering and Technologies: This area promotes the use of recyclable materials and environmentally benign technologies to prevent or mitigate the adverse environmental impacts of infrastructure construction and operation. These materials and technologies include green barriers to shield noise and improve air quality; paint and spray recovery systems; non-toxic and recyclable bridge and road coatings, asphalt mixes, and additives; geotextiles for slope stabilization and surface-life extension; and use of recycled tires, plastics, and pavements in infrastructure applications.

Environmental Sustainability of Transportation Systems

Transportation systems are designed to support economic development and a variety of other societal goals. Thus, the environmental impacts of transportation systems are a subset of the broader impacts of the land uses and other systems served by transportation. Within this context, transportation systems have been recognized as having major impacts on environmental sustainability. The transportation sector accounts for about one-third of domestic contributions to greenhouse gas emissions and is the fastest growing contributor both domestically and internationally. Transportation sector impacts upon the health of soils and aquatic resources, as well as habitat disruption, are often irreversible, with unknown long-term ecological consequences. The land use decisions made by governments and individuals are long-lasting and to a large extent determined by the availability of inexpensive transportation choices.

Initiative: Environmental Sustainability of Transportation Systems.

Goal: Investigate the technological and behavioral implications of alternative transportation infrastructures and development patterns to determine those that minimize impacts on long-term environmental sustainability.

Participants: DOT; EPA; DOE; HHS; HUD; the private sector; academia; non-governmental organizations; and State and local government agencies.

Benefits: Improved ability to understand the linkages between transportation and the environment, and how more sustainable transportation systems benefit society.

These issues are not easy to address and create substantial challenges for the research community. Finding solutions that enhance the sustainability of transportation systems requires applications of technology, as well as an understanding of the behavioral and social sciences. Research is needed to determine the technology necessary to design transportation systems and development patterns that provide access to economic, social, and recreational opportunities such that permanent (i.e., unsustainable) environmental degradation is minimized or avoided.

Examples of potential research areas under this initiative are:

Behavioral research associated with development patterns: Technical solutions for devising development patterns that produce environmentally cleaner and safer environments are a means of reducing VMT, both to reduce environmental problems and to increase the safety of communities. Research is needed to determine how aspects of human behavior such as mode choice, travel demand, and driver behavior are affected by development scale, the scale of hierarchical transportation infrastructures, and their interaction.

Impacts of transportation infrastructure on climate change: Providing additional transportation capacity "induces" or attracts new trips, as acknowledged by the recent Transportation Research Board special report, *Expanding Metropolitan Highways*. Both short-term and long-term effects tend to reduce any initial travel-time benefits associated with increases in capacity. Additional research is needed to clearly document both short- and long-term effects, especially the implications for greenhouse gas emissions. Research is also needed to determine whether transportation infrastructure can be designed in concert with development patterns such that accessibility is maximized.

Information technologies and sustainable development: Many information technologies offer solutions that can increase the sustainability of transport systems, especially when combined with development patterns that are more sustainable. For example, telecommuting offers the promise of accessibility without mobility and may be particularly beneficial for promoting development of sustainable communities. Research into the behavioral implications of telecommuting and other information technologies, such as adaptive transit dispatching, can identify the implications for sustainability, such as whether they result in major changes in travel demand and patterns. Likewise, any institutional or technological barriers to the application of such "virtual travel" approaches need to be identified for subsequent action.

Infrastructure needs associated with revitalizing urban areas and cleaning up brownfield sites: Brownfields typically are abandoned sites which are mildly contaminated but require only minimal clean-up efforts. Redevelopment of these and other urban sites can promote sustainability, since these uses can eliminate the need to put new development projects outside urban areas. Urban infill development can reduce the need for building new transportation infrastructure and reduce VMT growth. Urban brownfield sites also often have unmet infrastructure requirements that need to be addressed. Technological solutions, such as information technologies, may be able to identify and facilitate clean-up requirements while providing a transportation solution for abandoned urban areas.

Sustainable freight movement: Efforts to reduce traffic congestion and emissions in urban areas have often taken the form of restrictions on freight movement in favor of facilitating personal (primarily single-occupant-vehicle) travel. Additional research is needed on the long-term regional economic and environmental impacts of current freight policies and opportunities provided by new information technologies, intermodal facilities, and market-based measures for improving the energy efficiency of freight movement in urbanized areas.

Overall, this partnership initiative will address the sustainability of building and operating the interrelated and complex systems of transportation and development that drive, and are driven by, economic activities. The focus will be on behavioral sciences and interactions with technology in determining how people react to different systems to achieve sustainability.

APPENDIX C

ACRONYMS AND ABBREVIATIONS

ADA	Americans with Disabilities Act of 1990
ATTB	Advanced Technology Transit Bus
CAAA	Clean Air Act Amendments of 1990
CERF	Civil Engineering Research Foundation
CTRD	Committee on Transportation Research and Development
DARPA	Defense Advanced Research Projects Agency, U.S. Department of Defense
DOC	U.S. Department of Commerce
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration, U.S. Department of Transportation
FHWA	Federal Highway Administration, U.S. Department of Transportation
FRA	Federal Railroad Administration, U.S. Department of Transportation
FTA	Federal Transit Administration, U.S. Department of Transportation

GPS	Global Positioning System
HHS	U.S. Department of Health and Human Services
HUD	U.S. Department of Housing and Urban Development
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITS	Intelligent Transportation Systems
MARAD	Maritime Administration, U.S. Department of Transportation
MPO	Metropolitan Planning Organization
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration, U.S. Department of Transportation
NIST	National Institute of Standards and Technology, U.S. Department of Commerce
NRC	National Research Council
NSF	National Science Foundation
NSTC	National Science and Technology Council
NWS	National Weather Service, U.S. Department of Commerce
OST	Office of the Secretary of Transportation, U.S. Department of Transportation
OSTP	Office of Science and Technology Policy, Executive Office of the President
PNGV	Partnership for a New Generation of Vehicles
R&D	Research and Development

S&T	Science and Technology
TMIP	Travel Model Improvement Program
TRANSIMS	TRansportation ANalysis SIMulation System
USCG	United States Coast Guard, U.S. Department of Transportation
VMT	Vehicle-Miles Traveled

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ABSTRACT

The National Science and Technology Council's (NSTC's) Committee on Transportation R&D (CTRD) has prepared the first comprehensive, Government-wide *Transportation Science and Technology Strategy,* which provides a framework for guiding Federal transportation R&D toward meeting national transportation goals, not simply those of individual Federal Departments. The Strategy is based both on analytical material (including a broad environmental scan and an assessment of the transportation system's current and future strengths, weaknesses, opportunities, and threats) and on consultations with all sectors of the transportation enterprise (solicited at a variety of outreach events, workshops, and roundtables held in conjunction with the National Research Council's Transportation Research Board).

The CTRD's *Transportation Science and Technology Strategy* establishes a four-tiered approach to develop a coordinated Federal transportation S&T program:

1. **Strategic Planning and System Assessment** activities help provide direction for future R&D in addressing national transportation goals, as well as establish a process for assessing the impact of those investments on the performance of the Nation's transportation system.

2. **Strategic Partnership Initiatives** identify opportunities for government, industry, and academia to apply their collective capabilities and resources to demonstrate and deploy technology solutions to national transportation challenges, such as improving mobility for aging and transportation-disadvantaged Americans.

3. **Enabling Research** develops the research and knowledge base that will create breakthroughs in transportation technology, foster innovation, and provide the new transportation technologies and options to make possible a human-centered transportation system for the Nation.

4. **Transportation Education and Training** provides the cadre of competent transportation professionals and increased public awareness necessary to develop and apply new options and technologies.

This Strategy is the first step in institutionalizing a collaborative transportation R&D strategic planning process not only within the Federal Government but also with the transportation enterprise that it serves. The hope is that this process will help the Congress, the White House, and the American people create a world-class transportation R&D enterprise that will be the engine for continued economic growth and prosperity and for improvement of the quality of life for its citizens.

For additional copies and further information, contact:

Dr. Fenton Carey, Executive Director, NSTC Committee on Transportation R&D
202-366-4434 (phone) 202-366-3671 (fax)

National Science and Technology Council Executive Secretariat
202-456-6102 (phone) 202-456-6026 (fax)

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